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Gender Differences and Digital Learning Games – *One Size Does not fit all.*

Joseph Osunde

School of Communications and Computing, The Open University, Milton Keynes, United Kingdom

Liz Bacon and Lachlan Mackinnon

Department of Computing and Information Systems, University of Greenwich, London, United Kingdom

joseph.osunde@open.ac.uk

e.bacon@gre.ac.uk

l.mackinnon@gre.ac.uk

Abstract: The intrinsic motivation demonstrated towards digital games provides the opportunity for its use as a learning tool irrespective of gender differences. This has resulted in the combination of the motivation of games with curricular content referred to as *Digital Game-Based Learning*.

While some related studies have argued that there are no gender differences in the motivational appeal of digital educational games, others present an opposing view.

This paper reports the result of an investigation into the motivational appeal of digital educational games for 11-14 years old girls and boys. There is evidence that this age group is pivotal to the *shrinking pipeline phenomenon* in which fewer females progressively engage with computer science education and careers.

The investigation involved a two stage study composed of a qualitative exploratory study, which identified the key criteria for the successful appeal of some digital entertainment games to young girls and boys and a main study. The main study generate both qualitative and quantitative data to further investigate the motivational appeal of digital educational games for learning basic computer science concepts for both girls and boys of age 11-14 years old. For the main study, two experimental games for learning basic computer science concepts were created based on the key criteria identified from the exploratory study.

The first included the game characteristics that appeared to support the motivational appeal of the girls. The second game was antithetical to the first. Both genders from the participating population engaged with both games and online questionnaires were used to capture data on their perception of both games.

The outcome of the investigation which involved 304 participants (girls = 152 and boys =152) from Southeast England, United Kingdom provided the empirical evidence in support of the argument that there are gender differences in the motivational appeal of digital educational game characteristics which can either support or thwart motivation i.e. *one size does not fit all*.

The result of this investigation should support educationists, researchers and digital educational game designers in having an *inclusive approach* towards the creation of digital educational games for learning.

Keywords:

Motivational appeal, Digital educational games, gender differences, inclusive approach and Digital Game-Based Learning

1.0 Introduction

Digital educational games are designed to promote learner engagement through motivational appeal. Therefore, a combination of this motivational appeal and curricular content has been used to create learning materials referred to as *Digital Game-Based Learning (DGBL)*. This has resulted in the creation of digital educational games for a wide range of subjects including geography, engineering, biology, computer science, mathematics etc. (Papastergiou, 2009; McLaren et al, 2017).

There is a consensus from related studies that digital educational games not only teach contents and skills but also do so in an efficient manner which supports long lasting learning (Calvo-Ferrer, 2017; Kim and Ke, 2017). However, there is little consensus on the possible gender differences in the motivational appeal of these games on learners.

This study investigates the motivational appeal of digital educational games for learning basic computer science concepts for girls and boys of age 11-14. This age group is the focus of the study due to its importance and the under-representation of girls in computer science education and careers.

This paper reports the results of an exploratory study, which were used in the main study to obtain empirical evidence on gender differences in the motivational appeal of digital educational games for learning basic computer science concepts. The rest of the paper is structured as follows: Section 2 presents related work. Section 3 describes the methodology for the investigation, section 4 is an analysis of the results obtained from the investigation and related discussions. Finally section 5 summarises the conclusions of the paper and the implication of the results.

2.0 Related work

A review of the related literature indicates that there are 3 main arguments with regard to the motivational appeal of digital educational games and gender.

The first argument suggests that there are no gender differences in the motivational appeal of digital educational games (Ke and Grabowski, 2007; Papastergiou, 2009, Koivisto and Hamari, 2014; Mekler et al, 2017). Rather, causality agents such as individual and situational factors account for the differing effects of games (Wang, Schneider and Valacich, 2012; Hamari, Koivisto and Sarsa, 2014).

The second argument suggests that there are gender differences in the motivational appeal of digital educational games (De Jean et al, 1999; Young and Uptis, 1999; Przybylski et al, 2011; Wu et al, 2011; Boyle et al, 2012; Powell et al, 2012; Possler et al, 2017). Huang et al (2013) and Ferguson and Olson (2013) further argued that there are gender differences in the motivational appeal of digital educational games but that these depend on the perceptions of the game characteristics which can either support or thwart motivation.

The third argument suggests that gender differences in the motivational appeal provided by digital games is a confounding variable correlated to experience rather than the true cause of the differences. (Ratan et al, 2015; Shen et al, 2016).

Whilst the first argument suggests that there are no gender differences in the motivational appeal provided by digital games, the second and third arguments both agree that there are gender differences in the motivational appeal provided by digital games but that the causal agent may or may not be due to gender.

Related studies also indicate that the content of digital educational games tend to present restricted gender roles, have gender identity issues and game characteristics that are unsupportive of the motivational appeal for girls (Hartmann and Klimmt, 2006; Shen et al, 2016). This study is an investigation into the differences in the motivational appeal of digital educational games for girls and boys of age 11-14.

3.0 Methodology for digital educational game investigation

The methodology for the investigation included an exploratory study and a main study. The exploratory study was designed to gain insights into the game characteristics from some successful digital entertainment games that support the motivational appeal for girls of age 11-14 (Osunde et. al, 2015).

The result obtained from the exploratory study indicated that the variations of a range of game characteristics can contribute to the motivational appeal of digital entertainment games. These game characteristics were referred to as *significant game characteristics* as they were re-occurring constructs elicited from the participants during the exploratory study. The game constructs are a narrative of how participants view the key criteria that can make a game appealing or unappealing to them. This concept is based on the Personal Construct Theory (PCT) developed by George Kelly in 1955 as a constructivist approach to learning, knowledge, resource and information acquisition (Kelly, 1955). The basis of the theory is that people continually construct their own models of the world and these models are tested against reality (Rugg and McGeorge, 2002).

To confirm this understanding, seven significant game constructs with categories that appeal to girls were identified for further investigation in the main study. The variations of the constructs referred to as the category pairings are shown in Table 1.

Table 1: Selected construct category pairings for further investigation in the main study

No	Female game constructs	Categories of appeal to female participants	Categories with antithesis appeal
1.	Age appropriateness	All ages/everybody	Teenage games suited for the age group
2.	Game violence	No violence	Violent
3.	Game graphics	Cartoons	Photographs
4.	Colour used	Bright colours	Dark colours
5.	Game character	Human with real scenarios	Animal in fantasy scenarios
6.	Number of players	Player interaction	Single player
7.	Storyline	Include a definite storyline	No storyline

3.1 Main study investigation technique

To successfully investigate if these games constructs can be used to create motivationally appealing digital educational games for learning basic computer science concepts with 11-14 years old girls, a suitable methodology had to be identified and applied. Two experimental digital educational games were customised from an existing digital educational game for learning basic computer science concepts. The first included the game constructs that appear to support the motivational appeal of the girls. The second game was antithetical to the first as the constructs included did not support the motivational appeal of the girls.

The participating population of the girls and boys engaged with both experimental games and their perception of both games were captured using online questionnaires.

3.1.1 Study sample size and materials

A total of 304 participants, comprising of 152 girls and 152 boys, engaged with both experimental games for the main study. The reason for this approach was to obtain two sets of data on the perception of both games for both the girls and boys involved in the study. The data collected from participants' engaging with each game included information on how much each game appealed to the participants, the appeal of the specific game characteristics used in the games, and the influence of each game on participants' perception of digital educational games.

As discussed in Section 3.1, an existing digital educational game was identified and customised to create two experimental games which included variations of game characteristics identified from the exploratory study.

The Google Blockly Maze game was considered as it met the study requirements (technical and educational) for customisation. Figure 1 illustrates *The Google Blockly Maze game* which was customised to create two experimental games for the investigation.

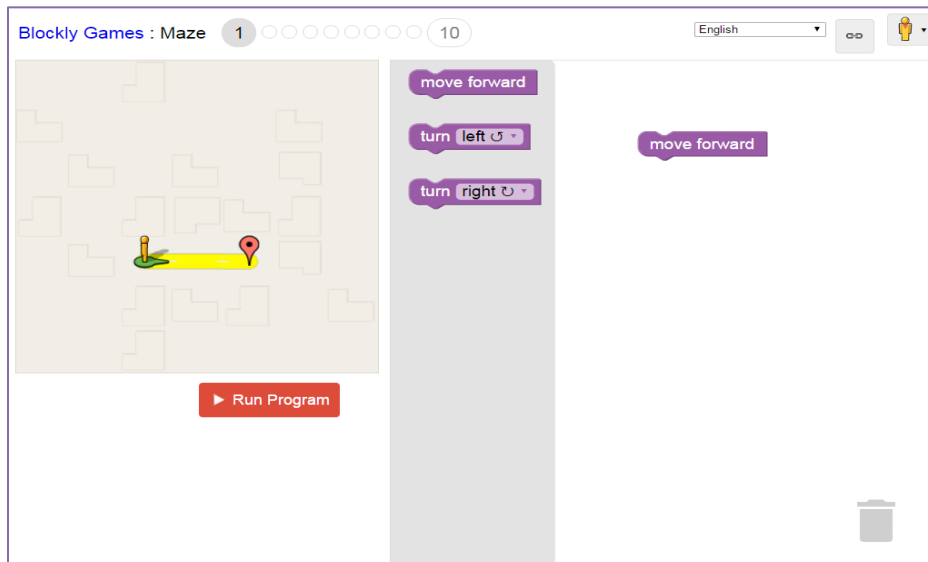
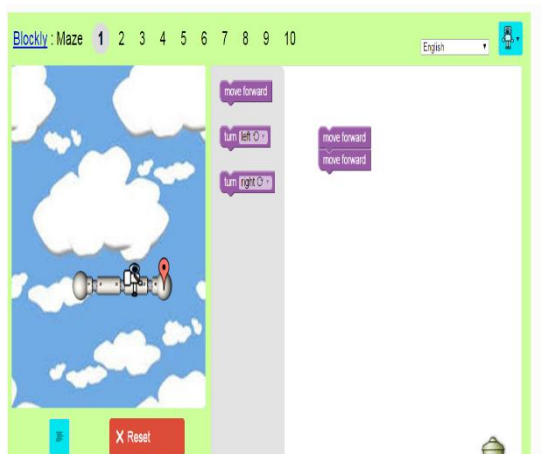


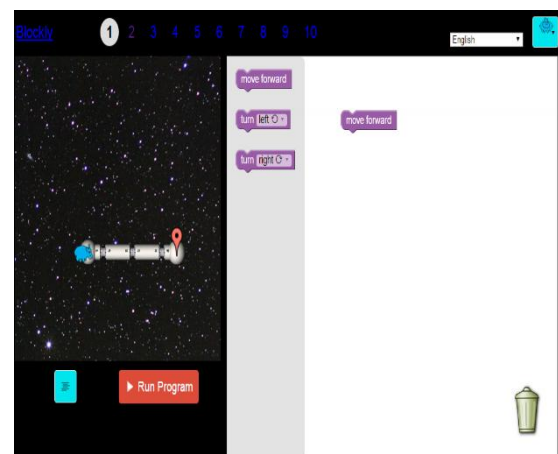
Figure 1: The Google Blockly Maze game

There are 10 levels of play in the gaming environment, each focuses on the use of different programming constructs such as *Sequencing*, *Decisions* and *Repeat (Loop)* instructions. The less challenging levels of the game allow the player to use an unlimited number of instruction blocks. However, the higher levels would allow a specified number of instruction blocks to successfully create the instruction, thus forcing the player to come up with a more efficient solution.

Figure 2 illustrates the customised experimental games (a) *The Lost Astronaut* and (b) *The Lost Hippo*.



(a)



(b)

Figure 2: Illustrations of the customised experimental games

As discussed in Section 3.1, online questionnaires (pre and post-study) were chosen and used to capture participant perceptions as it is a common technique for collecting survey data. The questionnaires were also used to measure preferences, opinions and intentions.

The pre-study questionnaire captured participants' perception and understanding of digital games before engaging with the games. The post-study questionnaire was used to collect participant feedback after engaging with the games.

The data collected using the pre and post-study questionnaires included the participant's identification number provided by instructors or teachers for anonymity purposes, and demographic information such as age and gender. The identification number was also required to correlate the pre and post-study data collected during the main study.

Other information captured using the pre-study questionnaire included information on entertainment gameplay habits (referred to as computer games in the questionnaire for simplification purposes for participants) and educational computer gameplay habits. The data captured from participants using the pre-study questionnaire elicited existing knowledge of significant game characteristics, perception and influence of digital educational games that appeal to the target audience. In addition, the existing knowledge of the influence and perception of digital educational games (referred to as educational computer games in the questionnaire for simplification purposes) was also captured using the pre-study questionnaire.

Three post-study questionnaires were created for the main study. One post-study questionnaire created for each experimental game and an evaluative post-study questionnaire. Two post-study questionnaires were used to capture participant responses about each game after engaging with them. The questionnaires also captured data on the appeal of specific game characteristics, the appeal of the game and the overall impact of the game. The evaluative post-study questionnaire captured comparative data on the impact of the games and which of the two games was more appealing to the target group. This information indicated the impact of the experimental games on the target audience by correlating the data with the pre-study data, exploratory study outcome and related literature.

The main study was conducted across five different locations in Southeast England comprising of 3 single sex schools (1 girl only and 2 boys only) and 2 mixed gender schools. The data collected on the boys' interaction with the experimental games were used for comparative analysis with the results obtained from the girls.

4.0 Results and discussion

The data collected from the evaluative questionnaire was analysed qualitatively and quantitatively to obtain insights into the comparative appeal of both games to the participating girls and boys.

4.1 The comparative appeal of games to participating girls and boys

The analysis of data collected using this questionnaire was used to identify if there were any significant differences in the appeal of the games, considering that they included variants of the selected significant game characteristics obtained from the exploratory study. The result is illustrated in figure 3. The analysis indicated that the girls found *The Lost Astronaut* more appealing in comparison to *The Lost Hippo* game. In contrast, the boys found *The Lost Hippo* more appealing than *The Lost Astronaut*.

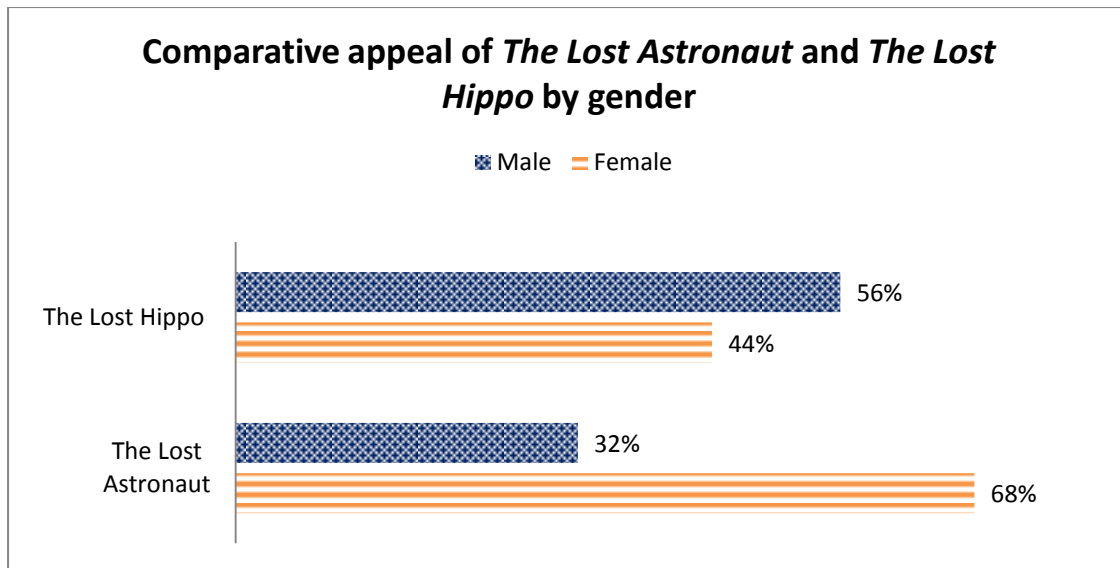


Figure 3: Comparative appeal of *The Lost Astronaut* and *The Lost Hippo* to participating boys and girls

To examine this result quantitatively in the context of the sampled population, a statistical analysis was conducted. A procedure to determine the normality of the distribution of the data was required for the generalisation of the result. A normality test was completed to confirm the distribution of the data within the sampled population.

From the test, there was an indication that the data was not consistently approximately normally distributed using the *Kurtotic check* (Doane and Seward, 2011), *Box plot* and the *Shapiro – Wilk test* (Razali and Wah, 2011). This test was repeated for all test data and they were identified to be not normally distributed. It was therefore assumed that the data captured for analysis was not normally distributed hence parametric analytical tools were not used for the quantitative analysis.

A non-parametric test that can measure the difference between two independent samples (*The Lost Astronaut* and *The Lost Hippo*) with ordinal data was considered and used. The *Mann-Whitney test* was used to test the significance of the difference in the appeal of the games to the participating population of girls and boys of ages 11-14. The result of the rank *Mann-Whitney test* is shown in Table 2. The mean rank value for the game appeal for the girls was 64.10 and the boys 76.95, which are significant differences.

Table 2: Rank test results for game appeal by gender

Ranks				
	Gender	N	Mean Rank	Sum of Ranks
<i>The Lost Astronaut</i>	F	80	64.10	5128.00
	M	58	76.95	4463.00
	Total	138		

Furthermore, the test statistics in Table 3 suggested that there were statistically significant differences in the distribution of the appeal values between girls and boys ($z=-2.154$, $p=.031$). The null hypothesis for the test statistics was that there is no significant difference in the appeal as indicated by participating girls and boys for the game if $p>0.05$. The null hypothesis was rejected here as the $p = 0.031$ i.e. there is a significant difference in the appeal indicated by participating girls and boys groups for the games.

Table 3: Test statistics for the significance of the game appeal difference.

Test Statistics ^a	
	Game
Mann-Whitney U	1888.000
Wilcoxon W	5128.000
Z	-2.154
Asymp. Sig. (2-tailed)	.031

From this test, there is evidence that difference in the appeal of *The Lost Astronaut* to the girls and *The Lost Hippo* to the boys is statistically significant.

4.2 Reasons for the preferential appeal of the games

The evaluative survey questionnaire also collected data for the reasons responsible for the differences in the appeal of the games between the genders. The significant game characteristics identified by the participating girls were game fun, social interaction, colour used, background used, graphics, the character used, ease of understanding, storyline and the appeal of the game. This result is illustrated in figure 4.

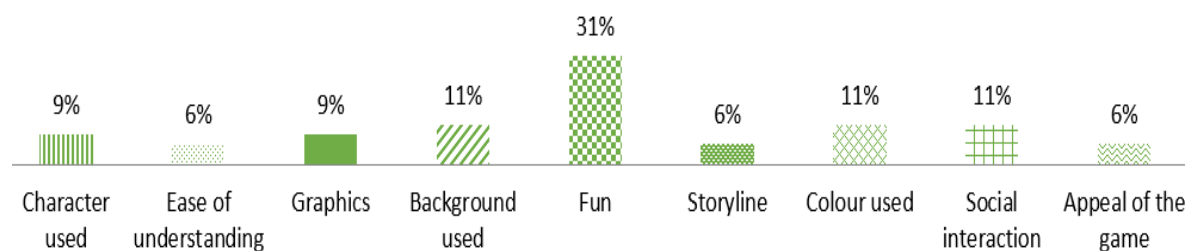


Figure 4: The reasons for the preferential appeal of *The Lost Astronaut* to participating girls

The main reasons for the preferential appeal of *The Lost Hippo* to the participating boys were also captured during the survey and illustrated in figure 5. The top six game characteristics were game fun, graphics, background used, the character used, ease of understanding and the colour used.

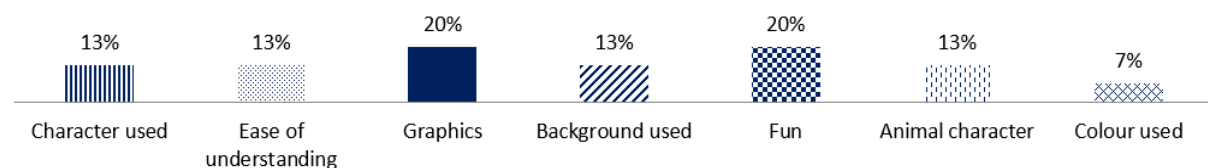


Figure 5: The reasons for the preferential appeal of *The Lost Hippo* to the boys

A comparison of the game characteristics mentioned by both genders shows a number of similarities. However, the difference was in the variation of the game characteristics, which would have been the reason for the difference in the appeal of the games. For example, fun, graphics, the character, the colour and background used are similar game characteristics. The difference was variants of these game characteristics used in both games. From the quantitative and qualitative analysis of the results, there is evidence to suggest that there are gender differences in the appeal of digital games for learning with the participating population.

5.0 Conclusion

Although digital educational games are used to engage young learners, there is a disparity in the understanding that digital educational games can motivate young learners equally irrespective of gender differences. This paper reports the investigation into digital educational games with a view to understanding if there are differences in the motivational appeal that they provide by gender and the reason for this difference.

The investigation provided the empirical evidence in support of the argument that there are gender differences in the motivational appeal provided by digital educational games to girls and boys. The study further provided the evidence to show that the variation of the game characteristics supports or thwart the motivation of the experimental games. This evidence further supports the findings by Huang et al (2013) and Ferguson and Olson (2013). While some of the game characteristics were significant to both genders, the variations of the characteristics were different.

The implication of the investigation supports an inclusive approach towards the creation of digital educational games for young learners *as one size does not fit all*.

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